DUMOND

An experimental study of the use of a disinfectant in rapid filtration of water

Municipal & Sanitary Engineering

B. S.

1910

AN EXPERIMENTAL STUDY OF THE USE OF A DISINFECTANT IN RAPID FILTRATION OF WATER

BY

LOUIS AUGUST DUMOND

THESIS

FOR THE

DEGREE OF BACHELOR OF SCIENCE

IN

MUNICIPAL AND SANITARY ENGINEERING

COLLEGE OF ENGINEERING

UNIVERSITY OF ILLINOIS

PRESENTED JUNE, 1910

UNIVERSITY OF ILLINOIS

June 1, 1910 190

THIS IS TO CERTIFY THAT THE THESIS PREPARED UNDER MY SUPERVISION BY

LOUIS AUGUST DUMOND

ENTITLED An Experimental Study of the Use of a Disinfectant in Rapid Filtration of Water

IS APPROVED BY ME AS FULFILLING THIS PART OF THE REQUIREMENTS FOR THE

DEGREE OF Bachelor of Science in Municipal and Sanitary Engineering

G. C. Habermeyer

Instructor in Charge

APPROVED: A N Talbot

HEAD OF DEPARTMENT OF Municipal and Sanitary Engineering

TABLE OF CONTENTS.

INTRODUCTION.

The necessity of protecting our public water supplies and the attendant rigid requirements for pure effluents from water and sewage purification has recently brought forth many developments in the methods of such purification. One of the most recent and important developments is the use of disinfectants to aid in reducing the number of bacteria in water or sewage. Disinfectants were first used as adjuncts to the various methods of sewage purification and were used later in the purification of public water supplies.

Various methods have been used for the sterilization of water. Among the most noteworthy are the following:

1. Heat
2. Lime
3. Acids
4. Ozone
5. Chlorine and Oxygen in Chlorine compounds.
   (a) Chlorine gas
   (b) Hypochlorites or oxychlorides
   (c) Electrolytic chlorine process
6. Copper or one of its compounds
7. Miscellaneous
   (a) Permanganates
   (b) Amine process
   (c) Sodium benzoate and other organic compounds.

Of these the only ones which have proven of practical value are the Ozone process, the use of copper salts, and the use of Hypochlorites in the form of bleaching powder. Of these processes, the use of Hypochlorites is at present the most economical. Of the hypochlorites, calcium hypochlorite CaCl.OCl, or bleaching powder, because of its cheapness is the one generally used.

In 1854 the Royal Sewage Commission of Great Britian used bleaching powder in deodorizing the London sewage. In 1855 the American Public Health Association found it to be the best disenfectant available, cost and efficiency concidered.

Among the European experiments upon the use of chlorine as a disenfectant may be cited those at Hamburg and Berlin. At Hamburg, Proskauer and Elsner experimented upon sewage which had been chemically precipitated by the Rothe-Degener process. They *obtained satisfactory disinfection of sewage with chloride of lime, using concentrations of chlorine ranging from 2.7 to 4.0 parts per million. Schunacher obtained a satisfactory disinfection of crude hospital sewage by the use of 43 parts per million available chlorine. At Berlin, Kranepuhl succeeded in removing all B. Coli from liter samples of crude Berlin sewage by using a concentration of 300 parts per million available chlorine. This test is more rigid than ordinarily required.

In the United States experiments bearing out the results of European investigat ors have been performed. The Lawerence Experiment Station early took up the problem of the use of a disenfectant as an adjunct to water purification. As a result of the

*U. S. G. S. Water Supply Paper No. 229.

investigations and numerous others carried on by private persons, cities, and state boards of health, the use of chlorine compounds in water purification, has, in the last year or two rapidly superceded the use of all other disenfectants.

As a result of these studies, many cities now use disenfection as the sole means of water purification. This should be done only when the amount of suspended matter in the water is relatively low. In other cities disenfection is used as a treatment preliminary to final filtration upon slow sand filters. In those cities where rapid sand filtration with preliminary chemical precipitation is used, bleaching powder is now introduced successfully at the same time as the precipitant. A notable example of this use of bleaching powder may be seen at the Bubbly Creek Water Purification Plant of the Union Stockyards Company, Chicago. Here, the water of Bubbly Creek which is dilute sewage, is given preliminary treatment with sulphate of alumina and bleaching powder before rapid sand filtration. An effluent is produced which passes the necessary chemical and bacterial requirements for human consumption.

In the use of bleaching powder, the following facts have been brought out.

1. Small amounts produce proper bacterial efficiency.
2. The amount required depends largely upon the amount organic matter in the water.
3. A large proportion of the bacteria in a water are killed by a contact of a few minutes only.
4. When bleaching powder is used as preliminary to fil-

tration, the subsequent filtration is simply an added factor of safety, as regards bacterial purification.

5. When bleaching powder is used in addition to a chemical precipitant, the amount of each required is reduced below the amount which would be required if either were used separately.

Among the water purification plants of the United States, the following recent installations may be noted as illustrative of the different ways in which bleaching powder is used. At Nashville, Tennessee; Warren, Rhode Island; and Reading, Pennsylvania, bleaching powder is uded in connection with a chemical precipitant as a treatment preliminary to filtration. At Harrisburg, Pennsylvania and Quincy, Illinois, bleaching powder is applied to the water before it is run through mechanical filters. At Minneapolis, Minneapolis, Minnesota; Montreal, Canada; and Hartford, Connecticut the addition of bleaching powder is the only treatment given to the water.

THEORY OF THE ACTION OF BLEACHING POWDER.

Bleaching powder containing from 20 to 40 parts per million of available chlorine can be obtained in the market. It is largely manufactured in this country by the electrolysis of salt. Commercial bleaching powder consists of a mixed salt, calcium chloride and hypochlorite of lime. When applied to water, calcium chloride remains inert and it is the hyphochlorite of lime which produces sterilization.

When bleaching powder is added to water it is dissolved and the hypochlorite combines with the free and half bound carbonic acid in the water to form hypochlorus acid.

$$CaClOCl \text{ disolved} = HClO + CaCO_3$$

Hypochlorous acid is a very unstable acid and a powerful oxidizing agent. In the process of oxidizable substances in the water it breaks up and liberates free or nacent oxygen.

$$HClO = HCl + O$$

It is this free or nascent oxygen, which, acting as an oxidizing agent, destroys the lower forms of life found in the water.

In expressing results of treatment of water, the term available chlorine is often used to denote the concentration of the applied chemical, while, in the strict sense, it is not the chlorine, but the atomic or nascent oxygen which should be measured. However, since the available chlorine is a measure of the atomic or nascent oxygen liberated, it will be used throughout this thesis. Available chlorine represents the oxidizing power of chlorine. Hypochlorous acid in the presence of a reducing

agent is decomposed according to the following equation:

$$HClO = HCl + O$$

*The oxidizing power of this acid, or the available chlorine, is, therefore, two hydrogen equivalents per molecule, which is twice its total chlorine content, a fact which makes the term available chlorine a misnomer, but it has come into general use, and will be used throughout this thesis.

*U. S. G. S. Water Supply Paper No. 229.

SCOPE OF EXPERIMENTAL WORK.

The experimental work in this thesis was with bleaching powder used with a badly polluted water, that of Silver Creek, commonly known as the Boneyard, which flows through the campus of the University of Illinois. Experiments were also made upon the rate at which bleaching powder loses its strength with age.

A study was made of the reduction in bacteria and the amount of chemical required to treat such a water so as to make it harmless as a source of pollution to other streams to be used as sources of water supply. The selective action of bleaching powder upon the pathogenic forms of bacterial life, and the action of bleaching powder in connection with the rapid filtration of water.

GENERAL ARRANGEMENT AND DESCRIPTION OF APPARATUS.

Before taking up the method of treatment of the Boneyard water with bleaching powder, the details of the plant will be briefly outlined. The general arrangement of the different parts is illustrated by the diagram and photographs on pages 10 & 11. The plant consists of the following:

(a) Marsh pump single acting
2" suction, 1" lift, 1/2" steam main

(b) Overflow tank A., diameter 4' 1", depth 2' 5" with 2" overflow pipe located at top. The purpose of this tank is to maintain a constant head of water above the outlet pipe a, and thus maintain a constant flow of water into the treating tank D. The outlet pipe (a) is provided with an adjustable elbow by means of which the flow of water may be directed to the desired point in the mixing trough E. of the treating tank.

(c) Chemical tank B, diameter 4' 1", depth 2', capacity 195 gallons.

(d) Chemical regulating tank C, consisting of square tank 2' x 2' x 1' 5" with float valve attached to outlet pipe (b) by which a constant head is maintained on the outlet pipe (c) of the regulating tank.

(e) Wooden treating tank D 15' 1" by 7' 1" by 3' 9" capacity 2950 gallons. This tank is provided with baffles throughout its length in order to maintain

as far as possible, a constant rate of flow through the tank. At the end of the tank where the chemical and raw water are admitted is suspended a narrow mixing trough E which is provided with baffles throughout its length to insure a thorough mixing of the raw water and the applied chemical. This tank is provided with 1" effluent pipe which leads to the underdrains in the floor of the hydraulics laboratory.

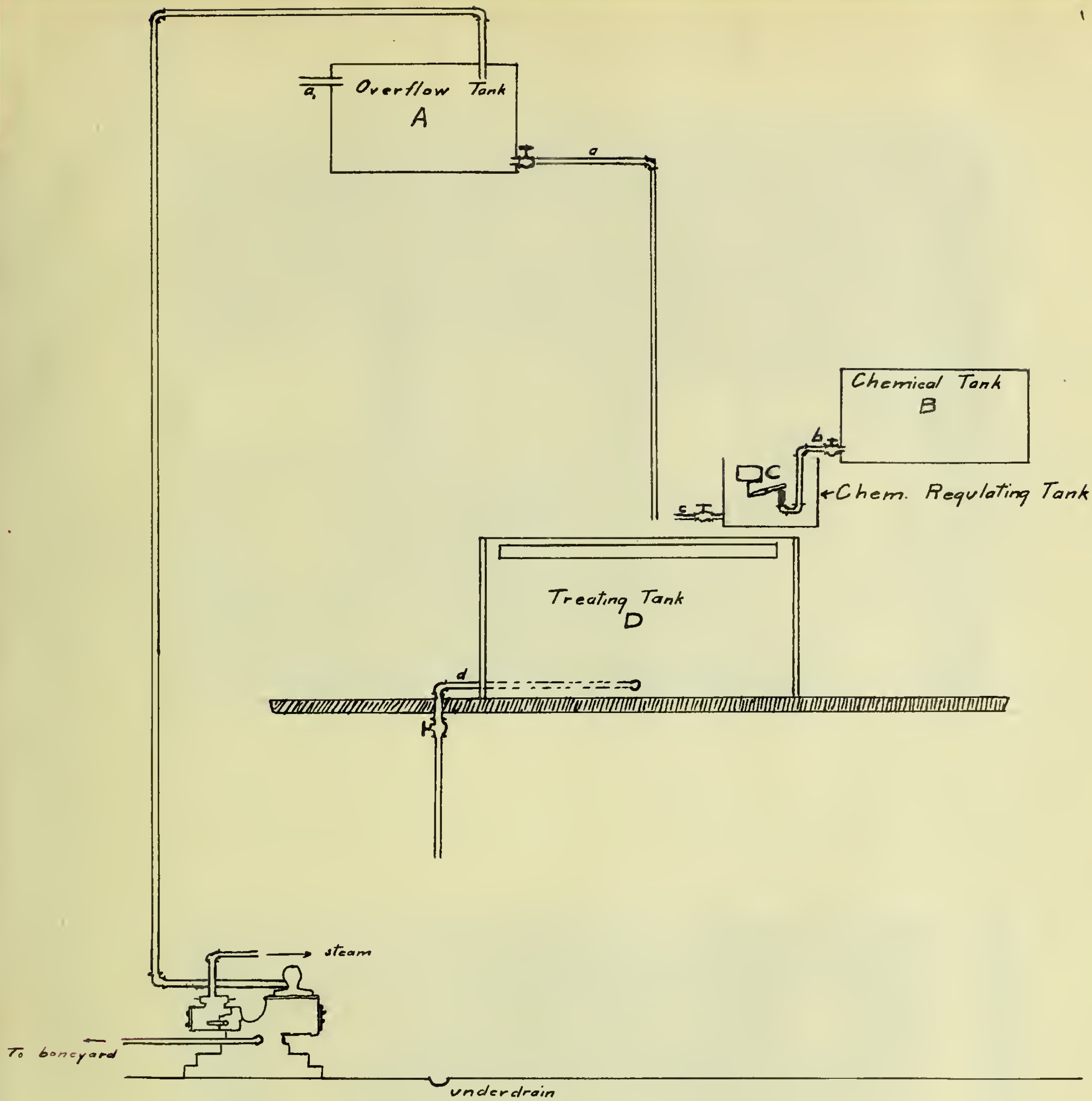
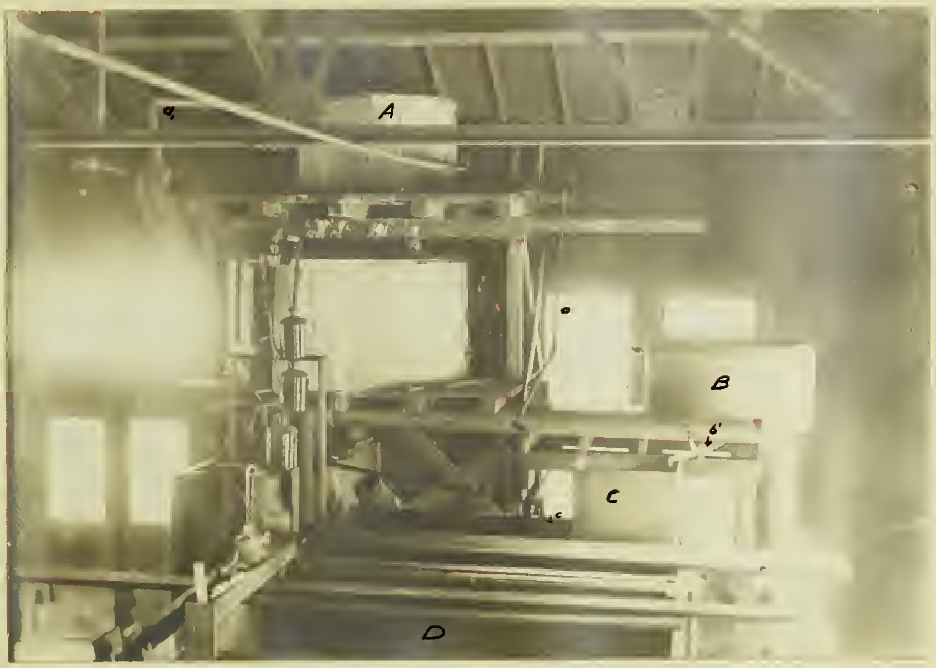


Diagram
Showing Arrangement
Of
Apparatus


A
B
C
D

METHOD OF TREATING THE BONEYARD WATER WITH BLEACHING POWDER.

All water used in the following record of tests was pumped from the Boneyard by the Marsh steam pump. The suction pipe of the pump extended within six inches of the bed of the stream in order to avoid as much as possible the oil which at times floats upon the surface of the water.

The raw water was pumped into the overflow tank A the effluent pipe of which is provided with a valve. When the overflow tank A was full so that water was flowing from the overflow pipe a, and the valve in the effluent pipe a was wide open, the rate of flow into the treating tank D was 14.5 gallons per minute.

Since the rate of flow of the raw water into the treating tank D was thus constant, it remained only to regulate the flow of the chemical into the treating tank D. This was done by means of the float valve in the regulating tank C. In the actual running of a test the valve in the effluent pipe of the regulating tank C was closed, the valve in the effluent pipe of the chemical tank B was opened, and chemical allowed to flow into the regulating tank C until the float valve came into action. Then the valves in the effluent pipes of the chemical tank B and the regulating tank C were adjusted until the desired rate of flow was obtained, as determinded by noting with a stop watch the time required to fill a cup holding 0.07825 gal. From the table following the number of pts. per million available chlorine was then calculated.

In these tests one pound and five tenths pound solutions were used. By a one pound solution is here meant one in

which the water and chemical are mixed in the proportion of one pound of chemical to one hundred gallons of water.

Table showing relation between pts. per million av. Cl. and gallons of water.

1 lb.Sol. gal.	Water gal.	pts/1000000 Av. Cl.	0.5 lb. Sol. gal	Water gal	pts/1000000 av. Cl.
1	420	1.0	1	210	1.0
1	400	0.84	1	250	0.84
1	550	0.765	1	300	0.70
1	600	0.700	1	350	0.60
1	650	0.646	1	400	0.525
1	700	0.600	1	450	0.466
1	750	0.560	1	500	0.420
1	800	0.525	1	550	0.382
1	850	0.494	1	600	0.350
1	900	0.466	1	650	0.324
1	950	0.442	1	700	0.300
1	1000	0.420	1	750	0.282

In mixing the solution in preparation for a test the effluent pipe of the overflow tank A was disconnected below the valve and a horizontal piece of pipe connected in its place so that the effluent of the overflow tank A was wasted into the chemical tank B, until it became full. Then the desired amount of chemical required as determined from the above table was weighed out. All chemical used in these tests was purchased from the Dow Chemical Co. of Midland, Michigan. The quality of the chemical used was 35 per cent, that is, there was 0.35 lb. available CL in each pound

of the chemical. After the chemical had been weighed out, all the lumps were pulverized in the hands till the whole was of about the consistency of flour. This finely powdered chemical was then distributed upon the surface of the water in the chemical tank B and allowed to settle to the bottom. From time to time before starting the test and at longer intervals during the operation of a test the solution was thoroughly stirred with a long rod.

The general procedure in running a test was as follows: About four o'clock in the afternoon of the day in which the test was run the steam pump was started and the water pumped was wasted thru the effluent pipe of the treating tank D into the underdrains in the floor of the Hydraulics Laboratory. The pump was run for an hour or two in order to insure its steady action. About six o'clock the chemical was mixed. About seven o'clock the rate of flow of the chemical was adjusted, the effluent pipe of the treating tank D still remaining open. By seven thirty the rate of flow of the chemical was adjusted, the effluent pipe of the treating tank D was closed and the test started. During the test, care was taken to keep the mixing trough E level, and to so adjust the movable elbow upon the effluent pipe of the overflow tank A that the raw water would fall into the mixing trough E at the same point as the chemical from the regulating tank C. At about ten thirty the treating tank D would be full and the effluent pipe (d) would then be opened. The operation of the whole plant was then watched till eleven o'clock when it was left to run alone. At intervals during the test the rate of flow of the chemical was checked. The next morning at seven thirty the rate of flow of the chemical was again checked and samples of the raw water and the treated water

taken in standard bacteriological bottles. The cubic capacity of the tank was equal to about two hours flow.

Bacteriological Work.

The samples of raw water and treated water were plated upon standard lactose litmus agar plates and incubated at 37° for twenty-four hours. In the presumptive test for B. Coli, dextrose broth tubes were inoculated with the raw and treated water. All results recorded + indicate that from 25 to 70 per cent of gas formed in the closed arm of the fermentation tube and that B. Coli were probably present. Results recorded - indicate that no gas or less than 10% was formed. When the amount of gas formed is between 10 and 25% or more than 70% the results are considered atypical. In plating the raw and treated water one cu. cc. of dilutions of 0.1, 0.01, and 0.001 were used. After twenty-four hours incubation at 37° the total number and the number of red colonies developing and the results of the presumptive were test noted.

METHOD OF CONDUCTING TEST FOR DETERMINING RATE AT WHICH BLEACHING POWDER LOSES ITS STRENGTH WITH AGE.

A tenth normal solution of the bleaching powder to be tested was prepared, using distilled water. A tenth normal solution is one in which one tenth of a gram molecule of the substance is dissolved in one liter of water.

In testing for available chlorine, 25 cc. of the $\frac{N}{10}$ $CaClOCl$ solution was placed in a beaker. An excess of iodine (I) is assured in the sample by adding 10 cc. of a $\frac{N}{10}$ KI solution. The mixture was then acidified with hydrochloric acid (HCl). In this solution Cl is liberated from the $CaClOCl$ which free chlorine in the presence of KI liberates an equivalent amount of iodine (I)

$$Cl_2 + 2KI = 2KCl + I_2$$

The amount of this free iodine is measured by titrating the solution with thiosulphate ($\frac{N}{10}$ Na_2SO_3), using a starch solution obtained by boiling starch in water, as an indicator added near the end point. Now, the amount (Na_2SO_3) required to discharge the blue starch color is a measure of the amount of chlorine liberated from 25 cc. of the original mixture. All of the Cl will be liberated since K has a greater affinity for Cl than for I. The percentage of available chlorine is now calculated from the relation:

$$1 \text{ cc. } \frac{N}{10} \text{ thiosulphate} = 0.012 \text{ g. I} = 0.00355 \text{ g. } Cl.$$

In running the test, the $CaClOCl$ solution was mixed in a large bottle which was left unstoppered. Each day after taking a sample for tests, the whole solution was shaken and allowed to stand until after sample was taken on the following day.

RESULTS OF TESTS.

Tests upon Reduction of Bacteria.

No. of Test	Pts. per Million Av. Cl.	Bacteria Raw Water	Bacteria Treated Water	No. Red Colonies R.W.	No. Red Colonies T.W.	Presumptive Test T.W.	Presumptive Test R.W.	Per Cent Reduction
A	1.4	560000	200	51000	0	+	-	99.98
B	1.0	80000	1300	30000	0	+	+	98.37
C	1.0	15000	400	5000	100	+	-	97.5
D	1.0	500000	2100	3000	400	+	+	99.5
E	0.68	60000	1000	10000	10	+	-	83.5
F	0.68	300000	3500	100000	100	+	-	99.0
G	0.68	100000	100	40000	0	+	-	99.9

Flow approximately 1400 gallons per hour

R.W. = raw water
T.W. = treated water

REMARKS

Test

A Chemical ran uniformily. Rate of chemical checked several times during test.

B Same as for Test A.

C Same as for Test A.

D Same as for Test A. Water bad odor.

E Boneyard low and turbid. Water bad odor.

F Boneyard turbid, surface oily.

G Boneyard very turbid, water high, oil on surface.

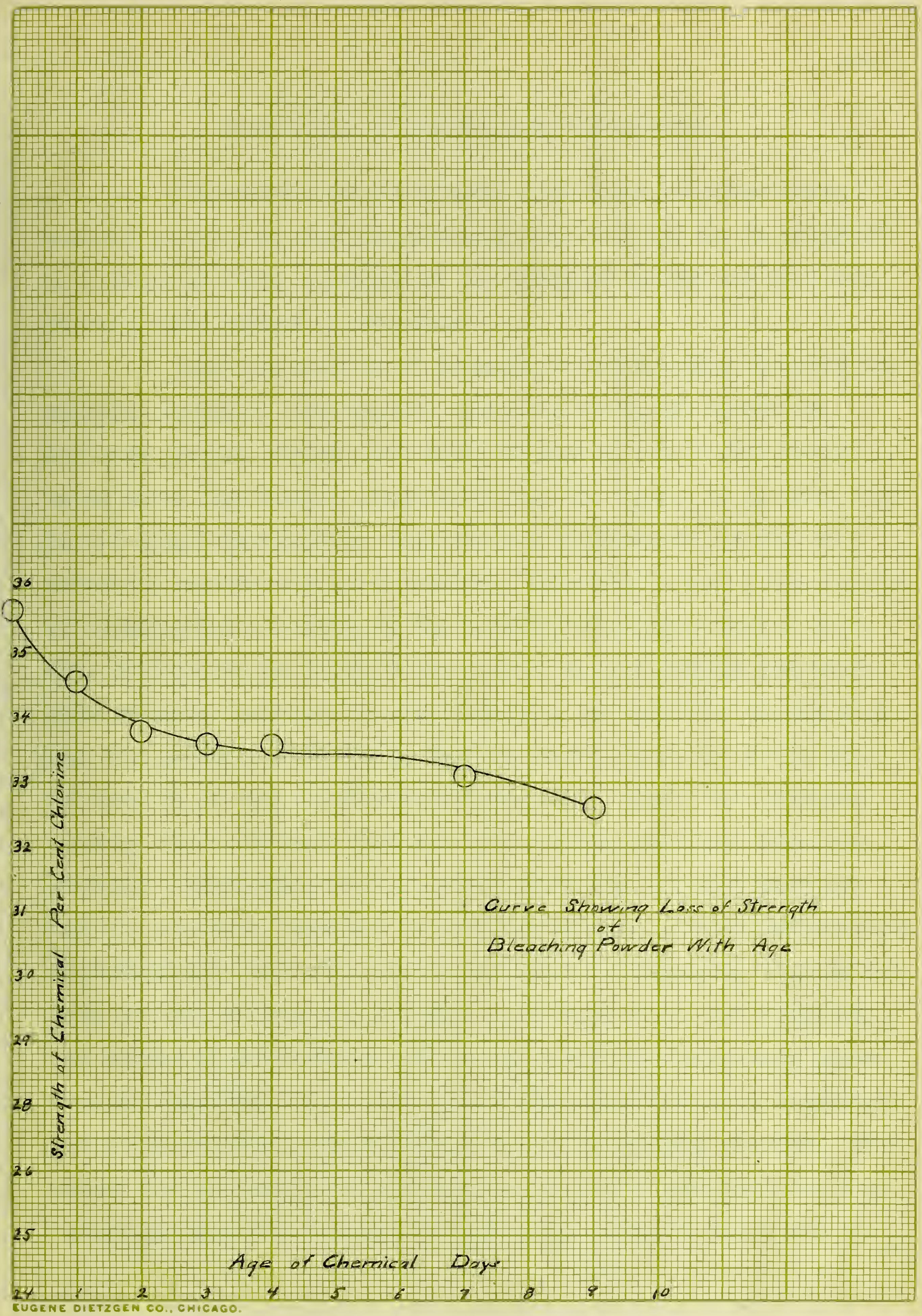
RESULTS OF TESTS.

Rate at which bleaching powder loses its strength with age.

Age in days	cc. of $\frac{N}{10}$ CaClOCl	cc. of $\frac{N}{10}$ Na_2SO_3	g. Cl per liter $\frac{N}{10}$ CaClOCl Sol.	Av. Cl. pts. per million	Strength per cent of original	Per cent loss
0	25	25.1	3.365	35.65	100	0
1	25	24.4	3.465	34.65	97.2	2.8
2	25	23.8	3.38	33.8	95.0	5.0
3	25	23.7	3.36	33.6	94.4	5.6
4	25	23.7	3.36	33.6	94.4	5.6
7	25	23.3	3.31	33.1	93.0	7.0
9	25	22.9	3.07	32.58	91.4	8.6

Boneyard water was treated on May 12 with 0.5 per cent solutions of CaClOCl three days old and fresh respectively. Proportion of 100 parts water to one of CaClOCl.

Bacteria per cc.			Presumptive Test	
Raw W.	3 days	fresh	3 days	fresh
100000	30	24	-	-


Curve Showing Loss of Strength
of
Bleaching Powder With Age
Strength of Chemical Per Cent Chlorine
Age of Chemical Days
36
35
34
33
32
31
30
29
28
26
25
24
1
2
3
4
5
6
7
8
9
10
EUGENE DIETZGEN CO., CHICAGO.

DISCUSSION OF RESULTS AND CONCLUSIONS.

The results recorded agree with those of other experimenters in showing that satisfactory disinfection can be produced in a water as badly polluted as the Boneyard by the use of a relatively small amount of chemical.

From the results of tests B, C, and D where one part per million available chlorine was used, and where the number of bacteria per cc. varied from 15000 to 500000, the higher limit being about the highest recorded during the tests, it is seen that in all cases satisfactory disinfection is produced, as far as reduction in bacteria is concerned. However, in test D the number of red colonies remaining in the treated water seems rather high. Now, looking at the results of tests E, F, and G where the available chlorine employed is only 0.68 pts. per million, we see that the disinfection produced is just as satisfactory as in the case of tests B, C, and D where more chemicals are used. The question arises; why is it that 0.68 pts. per million available chlorine produces satisfactory disinfection; while the use of 1 part per million available chlorine in one case did not produce satisfactory disinfection? This can only be explained by supposing that in the case of test D where satisfactory disinfection was not produced, the amount of suspended matter in the water was relatively higher than in the other tests under discussion, and that this suspended matter absorbed a certain proportion of the applied chemical, thus making the net amount of chemical in the water available for disinfection less than the results indicate. This is borne out in

part by noticing that the number of bacteria in the water was higher than in the other tests considered and that the water is recorded as having a bad odor. This same conclusion, that the suspended matter in the water absorbs part of the applied chemical has been reached by Earle B. Phelps in Water Supply Paper No. 229 on "The Disinfection of Sewage and Sewage Filter Effluents" and other investigators in trying to explain results similar to those in tests B, C, D, E, F, and G.

In test A, where 1.4 pts. per million available chlorine is used the disinfection produced is almost perfect. From the number of bacteria in the raw water, (560,000), it is probable that the amount of suspended matter present was as much as in test D where satisfactory disinfection was not produced. Hence we may conclude that 1.2 to 1.4 parts per million available chlorine would satisfactorily disinfect the Boneyard water so that it would not be dangerous as a source of pollution to other streams used for water supply. This statement must be qualified by saying, that, although sources of pollution to a water supply were disinfected, the water supply might still be dangerous if the suspended matter, much of which is of organic nature, were not removed. The general methods of removing suspended matter from water at present used in water purification plants are: Filtration thru slow sand filters where a rate of about 3,000,000 gallons per acre per day is employed, and filtration thru rapid sand or mechanical filters where a rate of about 125,000,000 gallons per acre per day is used. Where the amount of suspended matter is great, chemical percipitation may be used as a preliminary treatment to either, but is more often used with rapid sand filtration. Chemical

percipitation is generally employed as a preliminary treatment where the cost of cleaning filters or the troubles due to clogging of the upper sand layers would be greater than the expense of using a chemical precipitant.

The tests in general show that relatively more of the B. Coli than of the other forms of bacterial life are removed by chemical treatment with bleaching powder. From this we may conclude that bleaching powder does probably have a selective action upon the pathogenic forms of bacterial life.

From the results of the tests upon the rate at which bleaching powder loses its strength with age and the curve illustrating the same, it can be concluded that the loss of strength in a day or two is relatively small. Since, in all plants where disinfection is used, the chemical is mixed at least once a day due to the small capacity of mixing apparatus, this loss need not be considered. It is believed by the author that in plants where bleaching powder is used, the loss due to the non-disintegration of lumps of the chemical would be much greater than any ordinary loss due to age of the chemical.

Due to delays in getting the apparatus together, the first test was not run until April 14th, so that it was impossible to make the tests as extensive and varied as originally intended. The attempt was made to run a test on Tuesday and Thursday nights of each week, but due to the fact that at times the pump could not be made to work, or the valves of the pump would get out of order after the test was left to run alone at eleven o'clock, many tests were spoiled. The only tests which are recorded in this thesis

are those in which the pump ran so as to produce a constant flow of water from the overflow tank A. After the tests had been nearly concluded, it was decided that the effect of the absorption of chemical by the matter in suspension could be more clearly brought out by running tests on the raw water, in connection with the chemical tests, for total solids in suspension.

In order to show that a relatively small amount of bleaching powder is required when the matter in suspension is low, more tests should be run using a less amount of chemical.

In plants where bleaching powder is used as a disinfectant some method of mixing the chemical should be devised to avoid the disagreeable effects of the chlorine gas, liberated whenever bleaching powder is handled, upon the workmen.